

Short communication

Induction of bulb maturity of *Ornithogalum thyrsoides*Mark S. Roh^{a,*}, Ae Kyung Lee^b, Jeung Keun Suh^b^a US Department of Agriculture, Agricultural Research Service, National Arboretum, Floral and Nursery Plants Research Unit, Beltsville, MD 20705, USA^b Laboratory of Floriculture and Plant Physiology, School of Bio-Resources Science, Dankook University, Cheonan 330-714, Republic of Korea

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Abstract

The influence of bulb maturity at bulb harvest on growth and flowering response of *Ornithogalum thyrsoides* Jacq. ‘Chesapeake Starlight’ was investigated. Experiments were designed to determine if bulb maturity can be induced by bulb storage temperatures and whether bulb maturity can be evaluated by flowering responses. Bulbs with all senesced leaves at harvest were considered “mature” or with emerging young leaves and re-growing young roots were considered “immature”. Bulbs were potted after 0, 3, and 6 weeks of 30 °C or 2 weeks of 10 °C given either in the middle or at the end of 6 weeks of 30 °C. Mature bulbs, as compared to immature bulbs, took longer for leaves to emerge when control bulbs that did not receive any temperature treatment after harvest were planted upon harvest. Leaf emergence of the immature bulbs was significantly earlier than that of the mature bulbs. Mature bulbs which received 30 °C for 3 weeks (30 °C/3 week) flowered 31 days faster than immature bulbs and all bulbs flowered. Leaf emergence and flowering of mature and immature bulbs that received 30 °C/6 weeks or 2 weeks of 10 °C in the middle of 6 weeks of 30 °C (30 °C/2 weeks–10 °C/2 week–30 °C/3 weeks) did not differ from each other. Maturity can be induced by storing immature bulbs at 30 °C/6 weeks. Maturity, as evaluated by flowering percentage and days from leaf emergence to flowering, can be induced in *O. thyrsoides*. Immature bulbs can, therefore, be harvested for later forcing as long as bulbs are treated with 30 °C/6 weeks. It is proposed that maturity can be correlated with the speed of flowering and bulbs can be harvested at immature physiological state for forcing. Postharvest high-temperature treatment can be used to force immature bulbs that were harvested before the senescence of the leaves.

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1. Introduction

Ornithogalum is a tunicated bulb native to the South-Western Cape of South Africa (Du Plessis and Duncan, 1989). *Ornithogalum thyrsoides* and *O. dubium* bulbs are composed of 1 year old scales which are formed the previous year and new scales which are formed after inflorescence formation of the current year before bulb harvest (Roh and Jeong, 2004). At harvest, we believe that all bulbs are not at the same physiological status because of differences in the growth rate and extent of foliage senescence. Some bulbs still have green leaves that are senescing while leaves of other bulbs have completely senesced. These differences at harvest may contribute to the variations in growth and flowering responses following different bulb temperature treatments.

Growth and flowering of most geophytes is controlled by internal physiological factors, such as dormancy and maturity, bulb storage condition, and forcing temperatures (De Hertogh and Le Nard, 1993). The definition of dormancy and maturity in many geophytes is related to the date of bulb harvest and subsequent growth and flowering after various bulb storage treatments. This phenomenon has not been investigated in great detail, except in *Lilium longiflorum* Thunb. (De Hertogh et al., 1971; Roh and Wilkins, 1976, 1977a,b,c). *L. longiflorum*, a non-tunicated bulb, is also composed of bulb scales 1–3 years old with one or several shoot apices. Bulbs can be harvested at any time, even immediately after flowering, without losing the ability to emerge and grow (Roh and Wilkins, 1976). In *L. longiflorum*, bulbs matured as the dates of harvest were delayed, and mature bulbs were known to respond to a conventional bulb vernalization treatment (6 weeks of 4.5 °C treatment) and produced high flower buds counts (Roh and Wilkins, 1977b,c). When bulbs were harvested in late July, bulbs were considered immature, deep in dormancy, and did not

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respond to bulb vernalizing treatment. However, maturity was induced in these immature bulbs when treated with modified bulb temperature treatments [30 °C/6 weeks or 2 weeks of 10 °C in the middle of 6 weeks of 30 °C (30 °C/3 weeks–10 °C/2 weeks–30 °C/3 weeks)] that resulted in early flowering and increased flower bud numbers than would normally be observed in mature bulbs following a conventional vernalizing temperature treatment. Although the biochemical nature of a “maturity factor” is not fully understood, such a factor is apparently translocated through the basal plate of double bulbs when flowering is accelerated in response to bulb vernalization treatment (Roh and Wilkins, 1977c).

The time of *Ornithogalum* bulb harvest in relation to forcing conditions has not been investigated. Therefore, this study was initiated to understand and investigate the growth and flowering response of *O. thyrsoides*, ‘Chesapeake Starlight’ bulbs as influenced by the level of bulb maturity. The goal was to understand whether bulb maturity can be achieved by bulb storage temperatures (30 and 10 °C), and to investigate whether bulb maturity can be determined by flowering response to bulb storage temperatures.

2. Materials and methods

2.1. Plant materials

O. thyrsoides hybrid ‘Chesapeake Starlight’ was used for all experiments. Fifty virus-free bulbs (2 cm in circumference) were planted in a plastic box (20 cm × 30 cm × 10 cm) filled with ProMix BM (Premier Horticulture, Quakertown, PA, USA) and

grown in a greenhouse maintained at day and night temperatures of 16.5/16.0 °C, day (D)/night (N), respectively (Lee and Roh, 2001). Leaf explants (5 mm × 5 mm) were obtained from the youngest leaf and tissue culture propagated using a Murashige and Skoog basal medium supplemented with 0.5 mg/l α -naphthalenacetic acid and 3 mg/l 6-benzylaminopurine. Tissue culture conditions were as described (Roh and Wocial, 1989). Tissue cultured propagules were grown in a greenhouse maintained at 21/18 °C, D/N, and bulbs were harvested on 4 April, 1999, and stored at room temperatures maintained at around 20 °C until the initiation of the experiment.

2.2. Classification of bulb maturity

At harvest, leaves of one group of plants were senesced, dried, and no longer attached to the bulb. These bulbs were designated as “mature bulbs”. When these mature bulbs were harvested, all roots were also senesced and easily separated from the basal plates. Another group of bulbs had leaves that were still green, and leaves were cut off leaving 2.5 cm portion of the lower part of the leaves attached to the bulbs. When harvested, some of these bulbs also had re-growing young roots and emerging young leaves. These bulbs were designated as “immature bulbs”.

2.3. Temperature treatment after bulb harvest and greenhouse culture

Groups of both mature and immature bulbs (8–9 cm in circumference) received 30 °C for 3 weeks (30 °C/3 weeks), 6

Table 1
Effect of bulb maturity and bulb storage temperatures on growth and flowering of *Ornithogalum*, ‘Chesapeake Starlight’

Treatment temperature (°C)/during (weeks) ^a	Date of potting	Bulb maturity	Number of days to			Flowering (%)	Flower stem length (cm)	Number of leaves inflorescence	
			LE ^b	FL	LE-FL				
Control	April 13	Mature	127	296	169	23	54	8	2.1
		Immature	103	293	190	48	51	9	2.3
30/3	May 4	Mature	44	168	124	100	46	7	3.0
		Immature	53	199	146	78	41	7	2.8
30/6	May 25	Mature	59	196	137	100	41	7	3.2
		Immature	58	199	141	100	44	7	3.0
30/3–10/2	May 18	Mature	50	195	145	100	42	7	3.4
		Immature	52	227	175	69	38	7	2.9
30/3–10/2–30/3	June 8	Mature	74	223	149	100	42	7	2.9
		Immature	69	218	149	100	43	7	3.1
30/3–10/2–30/3–20/4	July 8	Mature	105	249	144	100	45	7	3.5.
		Immature	105	257	152	100	41	7	3.2
30/3–10/2–30/3–20/4–10/4	August 5	Mature	132	241	129	100	58	8	1.3
		Immature	132	243	131	100	59	8	1.0
Level of significance ^c									
Bulb maturity			n.s.	**	**		n.s.	n.s.	n.s.
Treatment			**	**	**		**	n.s.	**
HSD value at 1% level			17	21	19		8.6		1.79

^a Temperature/duration.

^b LE: leaf emergence; FL: flowering; LE-FL: number of days from leaf emergence to flowering.

^c n.s., **; non-significant, significant at 1% level.

weeks (30 °C/6 weeks), or a sequential treatment of 30 °C/3 weeks–10 °C/2 weeks–30 °C/3 weeks starting from April 13, 1999. Other treatment details are described in Table 1. Following the high-temperature treatments, bulbs were stored at 20 °C until root primordia were visible and then potted with or without 4 weeks of 10 °C treatment. There were 25 bulbs per treatment. Bulbs were potted singly into 10 cm pots filled with ProMix BM. At planting, 0.8 g of a slow-release fertilizer (0.8 g; 14N-6P-11.4K) was applied to the surface, and plants were irrigated every second week with a 15N-7P-14K water-soluble fertilizer at 1.33 g l⁻¹. Greenhouse temperatures and light irradiance was maintained throughout the forcing period as described (Lee and Roh, 2001).

2.4. Data collection and statistical analysis

The experiment was terminated 95 days from the flowering of the first inflorescence of control bulbs, and the total number of inflorescences that developed was counted at the end of the experiment. When an inflorescence was clearly visible through the leaves, it was counted. The number of days from planting to leaf emergence, when leaves emerged from the surface of the growing medium, was recorded. When tips of the leaves were visible at potting (>1 cm long), it was considered that those emerged in 2 days. The number of days from the date of bulb harvest on April 13 to flowering was recorded, with flowering defined as the first day when 2–3 flowers were open. Flower stem length (scape plus inflorescence) was measured from the surface of the growing medium to the tip of the inflorescence. The number of inflorescences was recorded as described previously (Roh and Hong, 2007). Each individual plant was considered as an experimental unit. Data were subjected to the analysis of variance and mean comparisons by bulb temperature treatments were done by Tukey's ω -procedures with the honestly significant difference (hsd) value at 1% (Michigan State University, 1989).

3. Results

When untreated bulbs were planted, it took an average of 127 and 103 days, respectively, for mature and immature bulbs to emerge from the date of potting (Table 1). However, flowering of the untreated bulbs took 296 and 293 days for mature and immature bulbs, respectively, and the difference is statistically insignificant. The flowering percentage of mature bulbs (23%) was lower than that of immature bulbs (48%). Mature bulbs which received 30 °C/3 weeks flowered earlier by 31 days than immature bulbs. No differences in leaf emergence and flowering was noticed when both mature and immature bulbs received 30 °C/6 weeks. However, flowering was significantly delayed when immature bulbs (227 days) received 30 °C/3 weeks followed by 10 °C/2 weeks (30 °C/3 weeks–10 °C/2 weeks) as compared to the flowering of mature bulbs (195 days) that received the same treatment.

Leaf emergence and flowering of mature and immature bulbs that received 30 °C/6 weeks or 30 °C/3 weeks–10 °C/2 weeks–30 °C/3 weeks treatments did not differ from each

other and all bulbs flowered. Mature bulbs that received 30 °C/3 weeks or 6 weeks, or when 10 °C/2 weeks was intercalated in the middle of 30 °C/6 weeks (i.e., 30 °C/3 weeks–10 °C/2 weeks–30 °C/3 weeks and 30 °C/3 weeks–10 °C/2 weeks–30 °C/3 weeks–20 °C/4 weeks) showed no significant difference in the days to flower. However, the flowering percentage was reduced when immature bulbs received 30 °C/3 weeks and 30 °C/3 weeks–10 °C/2 weeks. The time to flower from leaf emergence of immature bulbs receiving 30 °C/3 weeks or 30 °C/3 weeks–10 °C/2 weeks took significantly longer than those of mature bulbs. However, these differences were not observed when bulbs received a total of 6 weeks at 30 °C.

The number of leaves that ranged from 7 to 9 was not affected by bulb maturity and postharvest temperature treatments. The number of inflorescences was not affected by bulb maturity, but was reduced to 1.3 and 1.0, respectively, when both mature and immature bulbs received 10 °C/4 weeks at the end of 30 °C/3 weeks–10 °C/2 weeks–30 °C/3 weeks–20 °C/4 weeks sequential temperature treatment.

4. Discussion

Early leaf emergence of untreated immature bulbs suggests that *O. thyrsoides*, 'Chesapeake Starlight' has a relatively shallow dormancy and may continue to grow under favorable environmental conditions (Halevy, 1990). Insignificant differences in flowering of the untreated bulbs between mature and immature bulbs and in the time to flower from leaf emergence when both group of bulbs received 30 °C/6 weeks clearly indicates that maturity to flower as measured by the speed of flowering was inducible from immature bulbs by postharvest high-temperatures treatment in *Ornithogalum* as was reported in *L. longiflorum* (Roh and Wilkins, 1977b,c). Maturity to flower (floral maturity) which can be influenced by bulb temperature treatments of immature bulbs cannot be measured by the number of total inflorescences produced. In *L. longiflorum*, however, the number of flowers was increased when immature bulbs received low–high–low-temperature treatment (Roh and Wilkins, 1977b,c).

Based on the results presented in this study, the speed of leaf emergence can be used to measure the level of dormancy, but is not related to the bulb maturity of *O. thyrsoides* as was discussed in *L. longiflorum* (De Hertogh et al., 1971), since leaf emergence was not affected by bulb maturity. Based on the flowering responses, maturity and immaturity in *O. thyrsoides* can be evaluated by flowering responses. Six weeks of 30 °C was required to induce or achieve maturity. Once bulbs reached to maturity by exposing bulbs to 30 °C/6 weeks after harvest, flowering response was not affected by the physiological condition of bulbs at harvest. Acceleration of flowering, increased scape length, and the number of inflorescences produced per bulb when bulbs received 10 °C at the end of treatment may not reflect the physiological condition of the bulbs at harvest. Because bulb maturity can be induced by bulb temperature treatments, bulbs can be harvested even when bulbs have green leaves attached.

The results can be interpreted that 30 °C treatment is not for inducing bulb maturity but for shortening the dormancy. However, *O. thyrsoides* can continuously grow and flower at an optimal conditions and do not enter dormancy (Halevy, 1990). There is a good possibility that the mature bulbs and also immature bulbs may enter the dormancy period after harvest, as the days to leaf emergence of immature bulbs was significantly delayed. The requirement to induce maturity from immature bulbs may require extended duration of high-temperature treatment which may affect the dormancy, if induced, and also affect the physiological stages. Mature bulbs treated for 30 °C/3 weeks and immature bulbs treated for 30 °C/6 weeks seems warranted for improved flowering percentage.

Dormancy, maturity, and immaturity is a very complex physiological phenomena as investigated in *L. longiflorum* (Roh and Wilkins, 1976, 1977a,b,c) and further studies are required to understand whether these three physiological stages in *Ornithogalum* are related and whether the terms, maturity and immaturity, do properly describe the physiological stages. Further, the concerns whether or not using terms of maturity and immaturity and expression on the induction or achieving of maturity from immature bulbs should be addressed in the future. However, studies on the maturity and induction of maturity from immature bulbs have been limited to *L. longiflorum* (Roh and Wilkins, 1976, 1977a,b,c) and are quite unique, and it is proposed to accept this terminology and the usage as they are used in this report.

5. Conclusion

O. thyrsoides bulbs can be harvested and forced in any physiological stage of maturity at harvest described in this study as long as mature bulbs are treated for 3 week at 30 °C after harvest. With immature bulbs, the 6-week treatment seems warranted for improved flowering percentage. Although the role of high temperatures given to bulbs immediately after harvest is not clearly understood (Rees, 1992), floral maturity if measured by the speed of flowering, i.e., days to flowering and days from leaf emergence to flowering, can be induced from immature bulbs. Dormancy and maturity in *Ornithogalum* are not related physiological phenomena or bulb maturity is not related to physiological dormancy. Based on these results, bulbs

can be harvested even if all leaves are not senesced, thus facilitating bulb harvest without concern for successfully forcing bulbs with green leaves at harvest. Postharvest treatments described here are sufficient to induce the maturity required for flowering, regardless of the bulb physiological states at harvest.

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